Third United Nations International Conference on the Peaceful Uses of Atomic Energy

A/CONF.28/A/686
SWITZERLAND
February 1964
Original: FRENCH

Confidential until official release during Conference

Abstract

THE EVOLUTION OF FISSION RATE DURING AND AFTER SHUTDOWN OF A NUCLEAR REACTOR

by P. Schmid and W. Zünti
Swiss Federal Institute for Reactor Research,
Würenlingen / Switzerland

The evolution of the fission rate during and shortly after fast shutdown of a nuclear reactor may contribute essentially to the total heat released to the fuel and is, therefore, subject to estimates both by the design engineers and by safeguard officers. Furthermore the shape of the function representing neutron flux at any location versus the time elapsed after sudden insertion of control absorbers contains essential and reliable information about reactivity in the particular shutdown state. The latter fact has been explored, e.g., by recently developed reactivity measurement techniques called "modified rod drop method".

The present paper summarizes useful knowledge about shutdown phenomena acquired at this institute while carrying out computations and experimental programmes of the types mentioned above. Upper and lower bounds are found for the fission rate during the finite travel time of the shut-off device. From this an equivalent reactivity step is defined such that the asymptotic evolution of fission rate is matched. For the fission rate after the shut-off device has reached its final position, an expansion into a series of characteristic functions of time is derived, the respective coefficients being given by the powers of the reciprocal reactivity in dollar units. This expansion converges well for final reactivities below -1 $ and proves very useful, not only for quick estimates of the fission rate, but also for optimum analysis of "modified rod drop experiments". An approximation

Translation provided by courtesy of the submitting Government

for the total fission energy E released after the initiation of a fast shutdown is presented for sub prompt critical excursions with initial periods T_o not shorter than the (properly defined) travel time θ of the shut-off device, the latter being driven in with constant acceleration.

The contribution E_I which would be observed with instantaneous, stepwise reactivity reduction from ρ_o to $\rho_o - |\Delta\rho|$ is given exactly by

$$E_I = \frac{r(0)}{|\Delta\rho| - \rho_o}\,\rho_o T_o ,$$

where $r(0)$ is the instantaneous fission rate at the releasing time of the shut-off device. The nontrivial contribution to E due to the inertia of the shut-off device, is defined by $E_\theta = E - E_I$. Replacing the actual regulating curve (reactivity versus travel distance) by a 2^{nd} order parabola well fitted near the initial position leads to the following bounds for E_θ:

$$\frac{r(0)}{|\Delta\rho| - \rho_o} \cdot \frac{\theta}{1 - \frac{\tau}{\rho_o T_o}}\, M_o\left(\frac{|\Delta\rho|}{1 - \rho_o}\right) \bar{D}\left(\frac{1}{T_o}\right) \leqslant E_\theta \leqslant \frac{r(0)}{|\Delta\rho| - \rho_o} \cdot \frac{\theta}{1 - \frac{\tau}{\rho_o T_o}}\, M_o\left(\frac{|\Delta\rho|}{1 - \rho_o}\right),$$

where τ is the reduced generation time, $\bar{D}(s)$ is the Laplace transform of the normalized delay distribution function and $M_o(x)$ is a non-elementary function specified and graphically represented in this paper.